

Having laid these Accounts before you, permit
me the Honour to be,

S I R,

Catharine Street, June 18.
1750.

Your most obedient

humble Servant,

H. Baker.

XVIII. *A Description of a Mariner's Compass
contrived by Gowin Knight, M. B. F.R.S.*

Read July 5. 1750. **T**HE Discovery of the Mariners Compass has probably been of more general and important Use to human Society, than the Invention of any one Instrument whatsoever: And yet so far have they been from studying the Improvement of it, that there would be no Absurdity in supposing that the first which was made might be as much superior to those in common Use now, as the most improved Instrument we have is superior to its first Contrivance.

The Compass which appeared before this *Society* last Year, on account of its being render'd useless by Lightning *, was what afforded me the first Idea of their Imperfections, some of which I then enumerated; but others have since occurred to me, arising from the Structure of the Needle, which I had not sufficiently considered at that time. It was then observed, that almost all the Compasses on board our Merchant-

* See these *Transactions*, N^o. 492, p. 111.

Merchant-Ships had their Needles formed of two Pieces of steel Wire; each of which was bent in the middle, so as to make an obtuse Angle; and their Ends, being applied together, make an acute one; so that the Whole represents the Form of a Lozenge; in the Centre of which, and of the Card, is placed the brass Cap. I procured twenty Cards, with Needles of this kind fixed to them; and after touching them with a Pair of large Bars, I tried each of them, with the same Cup and Pin, by drawing them aside 90 Degrees from the true Point, and then seeing where they would rest. I found them all to vary more or less, either to the East or West; and some of them as far as 8 Degrees. Few of them came to the same Degree twice together; and when they did, that was never the true Point. In short, they not only varied from the true Direction, but from one another, and from themselves. I then tried, by drawing them gently aside, how far I could make them stand from the true Point, without returning; and found they might frequently be made to do it at the Distance of a whole Point on either Side. One of them, which generally varied 6 or 7 Degrees to the East, being drawn the same Way, would stand at 16 Degrees.

All these Irregularities are owing to the Structure of the Needle: For the Wires, of which it is composed, are only hardened at the Ends; and that is done by making the Ends red hot, and quenching them in Water: If all these Ends are not equally hard, or if one End be hardened higher up than the other, when they come to be put together, in fixing them to the Card, that End which is hardest, will destroy
much

much of the Virtue of the other ; by which means the hardest End will have most Power in directing the Card, and must consequently make it vary towards its own Direction. If you retouch these Wires when fixed to the Card, the Error will still remain ; for that Wire which is best hardened will always become the strongest. Considering how uncertain this Method of hardening the Ends of the Wires must be, it is a great Chance if they should once in an hundred times be equally and uniformly hard : And unless they are, the Card to which they are fixed must necessarily vary.

The Wires being disposed in the Form of a Lozenge, is the Reason why these Cards had so little Force, that they might be made to stand at the Distance of several Degrees, on either Side the Point from whence they were drawn. For all magnetical Bodies receive an additional Strength, by being placed in the Direction of the Earth's Magnetism, and act proportionably less vigorously when turned out of it. Wherefore, when these kind of Needles are drawn aside from their true Point, two of the parallel Sides of the Lozenge will conspire more directly than before with the Earth's Magnetism ; and the other two will be less in that Direction : By which means the two first Sides will very much impede its Return ; and the two latter will have that Impediment to overcome, as well as the Friction, by their own Force alone.

The Needles that are used on board the Men of War, and some of the larger trading Ships, are made of one Piece of Steel, of a Spring Temper, and are broad towards the Ends, but tapering to-

wards the Middle, where a Hole is made to receive the Cap. At the Ends they terminate in an Angle greater or less, according to the Skill or Fancy of the Workman. Now, tho' the worst of these are infinitely preferable to those of Wire, yet the best of them are far from being perfect. Every Needle of this Form has 6 Poles instead of two. There is one at each End, two where it becomes tapering, and two at the Hole in the Middle. This is owing to their Shape; for the middle Part being very slender, it has not Substance enough to conduct the magnetic Stream quite through from one End to the other. All these Poles appear very distinctly, when examined with a Glass that is sprinkled over with magnetic Sand. Nevertheless this Circumstance does not hinder the Needle from pointing true; but as it has less Force to move the Card, than when the magnetic Stream moves in large Curves from one End to the other, it is certainly an Imperfection.

I examined an hard Needle of this sort, whose Ends were very broad, and terminated in an acute Angle; and observed, that, tho' its Motion was very free and vigorous, yet I could make it stand one Degree on either Side the true Point; and being at a Loss to account for it, I tried what Appearance it would make under a Glass with magnetic Sand, and discover'd that the magnetic Stream came out of the Sides, which formed the acute Angle at the Ends, in Lines that were almost perpendicular to those Sides, and then was bent round to go to the other Pole: From whence I concluded, that when the Needle was drawn a little from the true Point, the Stream, which came out of one of these Sides, would

would be more in the Direction of the Earth's Magnetism than before ; on which account it would act stronger in retaining the Needle in that Situation, than the Stream of the other Side in restoring it ; especially as that Stream would be now weaker, on account of its being turned out of the magnetical Line, and would have the Friction betwixt the Cap and Pin to overcome at the same time.

I tried two other Needles, whose Ends were formed into Angles very obtuse, and could not find that they were liable to the same Objection.

Two Needles, that were quite strait, and square at the Ends, were found to have only two Poles ; but about the Hole in the Middle the Curves were a little confused. These always came exactly to the same Point, after vibrating a long time ; and if drawn never so little on one Side, would return to it again without any sensible Difference. We may therefore conclude, that a regular Parallelopiped is the best Shape for a Needle, as well as the simplest ; with the Holes for the Caps as small as can well be contrived ; or if it can be made to answer the Purpose without any Hole at all, it will be still more perfect.

Yet the common Shape has one Advantage which this has not : For, being made broad at the Ends, and slender in the Middle, its Weight is removed as far as possible from the Centre : On which account, if it once points true, the Friction at the Centre cannot so easily put it in Motion ; and its Vibrations, when in Motion, will be slower ; so that their Limits may be more nicely observed, and the middle Point betwixt them is that where it would

stand, if at rest. Being unwilling to part with these Advantages, I contrived a light Circle of Brass, of the same Diameter with the Card, which will supply a Weight acting at the greatest Distance from the Centre of Motion, and also serve to support the Card; which may now be made of thin Paper, without any thing to stiffen it. So that the extraordinary Weight of the brass Ring is compensated in a great measure by the Lightness of the Card. This Ring is of Service in another respect; for, being fixed below the Card, and the Needle above it, the Centre of Gravity is placed low enough to admit of the Cap being put under the Needle; whereby the Hole in the Needle becomes unnecessary; and the latter being placed above the Card, renders it easier to be touched with a Pair of Bars.

Having thus completed the Needle and Card to my Satisfaction, what chiefly remains, is, to contrive such a Cap and Point as will have the least Friction, and be most likely to continue in a State of Perfection. The Caps in Use are either of Brass, a mixed Metal, like that of a reflecting Telescope, Crystal, or Agate. The two first will only admit of brass Points, and the latter are rather too expensive for common Use. Wherefore I bethought myself of trying glass Caps: I had three of them made by a Glass-blower, two of which I got polished: They were all set in Brass, so as to screw into the same Needle, which had also one of Agate fitted to it. I compared them with that of Agate, by trying with each of them how many Vibrations the same Card and Needle would make, when drawn aside 90 Degrees,

Degrees, on the same Point; which was a very small sewing Needle.

The Number of Vibrations with the Agate Cap, on the first Trial, were 39, then 37, then 39 again; with one of the glass Caps it made 23, and then 20. This Difference from the Agate Cap was so great, that I concluded the Point must be damaged, and therefore chose a finer; on which the same glass Cap made 41 Vibrations; then 43; and another glass Cap made 47, and the next time 43. But the Agate Cap with this Point made 51, 57, and 58 Vibrations. The unpolished glass Cap performed much the same with the others. I had two of them polished again by Mr. *Smeaton*; and in Company with him repeated the same Experiments; but with no better Success. The Agate Cap made always many more Vibrations than the glass one; and generally with the latter the Number diminished by repeated Trials; whereas with the Agate Cap it usually increased.

These Experiments made me lay aside the Thoughts of glass Caps, and put me upon thinking how Agate ones might be made with as little Expence as possible.

With this View I got a Cap turned of Ivory, in such a manner as to receive a small Bit of Agate at the Top. This being ground concave, and polished on that Side, where it formed the *Apex* of the hollow Cone in the Cap, was capable of answering the Purpose as well as if the Whole had been Agate, and was much lighter. These Caps may be made cheap enough for common Use; and, if good at first, cannot easily be impaired.

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For a Point, I chose a common sewing Needle, and contrived to fix it in such a manner as to be taken out with the greatest Ease, and replaced by another, if necessary; by which means an excellent Point may be always had with little Trouble or Expence. Common Needles, when well temper'd, have all the Qualifications that can be desired for the Purpose intended. The smallest are strong enough to bear the Weight of a Card; and are neither so soft as to be liable to bend, nor so hard and brittle as to break; and they are generally better pointed than any that a common Workman could pretend to make *extempore*.

Thus we have gone through all the Parts that are essential to a Mariner's Compass; and endeavoured to put them upon such a Footing, as to leave as little Room as possible for Error in their first Construction, or Failure in the long continued Use of them.

This, which I have now the Honour to exhibit to the *Society*, was made by Mr. *Smeaton*, a Gentleman whose uncommon Skill in the Theory and Practice of Mechanics has enabled him to execute whatever I proposed in such a manner as always to exceed my Expectations: And not only so, but he has added a considerable Improvement of his own. By a very simple Contrivance he has made the same Instrument capable of serving the Purposes of an Azimuth and Amplitude-Compass; and that in a manner much preferable to any thing hitherto contrived; the Description and Use of which he has drawn up himself, for the Perusal of the *Society*.